FINANCING RADIOACTIVE WASTE DISPOSAL

The Congress of the United States
Congressional Budget Office

NOTE

All cost estimates in this report are in fiscal year 1982 dollars unless otherwise noted. All costs are for fiscal years unless otherwise specified.

PREFACE

Radioactive waste, in the form of spent nuclear fuel, is now stored on electric utility sites in temporary facilities. The accumulation of these wastes is a significant source of concern to the utilities, their ratepayers, and the nuclear industry. Although the federal government is responsible for the ultimate disposal of these wastes, considerations of economic efficiency and fairness suggest that the costs incurred by the government in carrying out this responsibility should be borne by the recipients of the service--ultimately the users of nuclear electricity. The costs, however, are not likely to be a large addition to the price of electric service, even with serious cost overruns in the disposal program. This implies that, of all the complex issues surrounding radioactive waste disposal, financing the program should be the most tractable.

The most advanced, and perhaps sole, option for disposal of radioactive waste is burial in a geologic repository. The Department of Energy has developed a program for the construction and operation of two such repositories, which it estimates will cost $14.8 billion in fiscal year 1982 dollars. Since these wastes are a by-product of the generation of electricity using nuclear power, several proposals have been made to finance the program through a generation fee assessed on each kilowatt hour of electricity produced by civilian reactors. In response to a request by the House Committee on Interior and Insular Affairs, this report examines the level of such a fee required to finance the waste disposal program, and how such a fee would respond to changes in the costs and other aspects of the program.

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SUMMARY

Radioactive waste, in the form of spent nuclear fuel, has been accumulating since the advent of the commercial reactor program for nuclear-powered electric utilities. Because this material is potentially dangerous to human health, it must be carefully and permanently sequestered from the biological environment. This is true whether the waste material is the spent reactor fuel itself or the residual waste by-products produced by extracting useful elements from the spent fuel. The federal government is responsible for the ultimate disposal of radioactive waste, but development of a final disposal program has been sporadic.

Because the nation's electric utilities currently store large amounts of radioactive spent fuel in on-site interim facilities, many nuclear power plants are running out of interim space--29 nuclear units in this decade--and those that do may be forced to shut down or ship the waste to other locations where additional on-site capacity is available.

In response to these problems, plans are under way to construct a series of geologic repositories for long-term waste burial. The Department of Energy (DOE) program analyzed in this paper calls for the construction of two repositories that would be ready for fuel loading in 1994 and 1999.[1] The DOE repository program also includes research and development, site selection, construction of a test facility, provision for payments to state and local governments in whose jurisdictions the repositories would be located, operation and maintenance of the repositories during their lives, and final decommissioning (shutting and sealing) of the two facilities. This entire program is estimated to cost $14.8 billion in fiscal year 1982 dollars if it proceeds on schedule and if the DOE cost estimates are correct.

Considerations of economic efficiency, fairness, and effective program management all suggest that the users of nuclear-generated electricity should pay for this disposal service. With regard to economic efficiency, internalizing the costs of waste disposal would cause consumers of nuclear electricity to pay the correct price for their consumption. This would provide incentives for the least-cost mix of capital and fuels in the electric

1. The DOE schedule has changed since this analysis was written. The current schedule calls for completion of the first two repositories in 1997 and 2002. This change does not affect the conclusions of this paper, however.

industry. As to fairness, simple justice would imply that electricity consumers, who receive the full benefits of nuclear-generated electricity, should pay the full costs. With regard to effective program management, fees paid by electricity consumers might prove a more stable source of program funding in a period of budgetary constraint.

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In response to these concerns, legislation (passed by the Senate, S. 1662, and now being considered by the House) proposes that the waste disposal program be financed through a generation fee on each kilowatt hour of electricity generated by nuclear power. Calculation of the correct fee is complicated because the schedules of annual program costs and annual generation fee revenues are very different. While annual generation fee receipts are stable, annual program costs are relatively high early in the program (as the research and development and construction phases occur), low in the middle (as the repository is filled), and higher again when the repositories are decommissioned. If a fee were assessed to match the stream of annual costs, it would charge consumers of nuclear electricity early in the program a far higher price than would be charged later consumers for the same amount of electricity. An equitable self-financing program, therefore, must find some constant level (corrected for inflation) of generation fee that is sufficient to meet the program's total costs over its complete life.

A Waste Disposal Trust Fund

The asymmetry of annual program costs and revenues could be resolved through use of a trust fund to collect and disburse program revenues. In the program's early years, annual program costs will exceed generation fee revenues. During this phase the trust fund could borrow to meet its obligations. It would, of course, be responsible for interest payments on this borrowing. Once the repository is open and accepting waste, program costs will drop, and annual surpluses will occur. The trust fund would then retire its debt and invest its remaining surplus to earn interest (presumably through the purchase of government bonds).

Annual revenues from generation fees will cease when the last batches of fuel in the current program are withdrawn from their reactors. At this point, the surplus in the trust fund, together with the interest it has earned, must be large enough to cover the remaining program costs of interment of the last batches of waste and decommissioning the repositories. If a generation fee was set at the correct level, it would leave a surplus large enough to cover these final costs. Once the last dollar of the program costs has been paid, the trust fund should have a value of zero. If these conditions were met, the radioactive waste disposal program would be self-financing. Furthermore a correctly set fee should charge current and future electricity consumers the same price for the equal benefits. In this report, such a fee is termed an "optimal fee," that is, the fee that would be charged if the future were known perfectly.

EVALUATING THE GENERATION FEE

If the exact costs and scheduling of the radioactive waste disposal program were certain, then the calculation of the optimal fee would be complicated but unambiguous. But the world is not a certain place, and the history of the program to date suggests that the cost uncertainty normally associated with large, first-time engineering projects is compounded by difficult social and political questions, including licensing requirements for the repositories and the issue of their location. Thus, there is a reasonable probability that the optimal fee required to make the program self-financing will be larger than that suggested by the current DOE cost estimates. This raises two issues:

- How sensitive is the level of the optimal fee to changes in the assumptions underlying the program costs or the demand for repository services? and

- Who should bear the risk that the fees might have to be raised in the future in response to unforeseen cost increases?

Sources of Sensitivity in the Optimal Fee

Three major sources of sensitivity are analyzed in this report.

- The Level of Nuclear Generating Capacity. If a lower rate of growth in nuclear generating capacity is assumed, then the level of the optimal fee would increase since it would take longer to fill the repository, adding to the costs of its operation.

- Additions to the Current Definition of the Radioactive Waste Program. If other elements are added to the definition of the radioactive waste program, then the optimal fee would increase. Most probable potential additions include a Monitored Retrievable Storage facility (which would extend above-ground interim storage capabilities) and the government's assumption of responsibility for transportation of wastes from generation stations to the repository.

- Program Cost Overruns. If the waste disposal program experiences cost overruns, as is common to programs of this type, then the optimal fee level would increase significantly.

All of these potential changes would necessitate a higher level of the optimal generation fee. But two of them--changes in program definition and changes in the rate of growth in nuclear power--would not substantially change the fee required for a self-financing waste program. Under most reasonable assumptions regarding these two factors, the optimal fee would remain in the range of 1 percent of the cost of nuclear-powered electricity. But cost overruns would necessitate proportionate increases in the optimal fee level. Recent engineering studies suggest that cost overruns as high as 160 percent are plausible for initial projects of this type. If cost overruns of this magnitude occurred, they would require a parallel increase of 160 percent in the optimal fee.

The value of the optimal fee under a variety of assumptions is given in the Summary Table. If a high rate of nuclear growth occurs, then the optimal fee would be .483 mills per kilowatt hour. Under the other extreme assumption of very low nuclear growth, the fee would be .570 mills per kilowatt hour--a 20 percent increase, but still only about 1 percent of the cost of nuclear-powered electricity. For each of the four nuclear-growth scenarios analyzed in this report, the inclusion of transportation costs in the program also would lead to a 20 percent increase in the fee level, and the inclusion of a Monitored Retrievable Storage facility would add about 5 percent. Thus, these are not important sources of sensitivity in the optimal fee.

The optimal fee, however, would vary proportionately with cost overruns. A 40 percent cost overrun would increase the real level of the fee by 40 percent, and a 160 percent overrun would increase the fee by 160 percent. While this study does not predict such overruns and has not reviewed the methodology underlying DOE estimates, the history of comparable projects suggests that overruns of this magnitude cannot be ruled out.

These values for the optimal fee under cost overrun assumptions are oversimplified in one respect. They assume that the fee would be corrected for cost overruns at the onset of the program. It is more likely that the program would be well under way and into its construction phase before overruns could be gauged with any degree of accuracy. This raises the issue of risk. If cost overruns are not planned for, but do occur, then either the generation fees would have to be raised to recoup the overruns or the

SUMMARY TABLE. GENERATION FEE LEVEL REQUIRED TO CREATE A SELF-FINANCING REPOSITORY TRUST FUND, UNDER ALTERNATIVE ASSUMPTIONS, BY RATES OF NUCLEAR-POWER GROWTH (In mills per kilowatt hour, in fiscal year 1982 dollars)

Assumption	High Growth	Medium Growth	Low Growth	Very Low Growth
DOE Program Cost Estimates	.483	.517	.549	.570
Inclusion of Transportation Costs	.592	.633	.664	.669
Inclusion of a Monitored Retrievable Storage Facility	.506	.541	.577	.600
40 Percent Cost Overrun	.672	.718	.764	.792
160 Percent Cost Overrun	1.238	1.324	1.407	1.458

government would have to provide the additional funds. In this situation, current electricity consumers would be subsidized by future ones, since they would not have paid their "fair share." But if overruns are planned for yet do not occur, current consumers would have overpaid their share and would have subsidized future ones. Thus, the major issue concerning the setting of the generation fee is: who should bear the risk of substantial cost overruns in the radioactive waste disposal program?

Options for Assigning the Financial Risk

This report examines four approaches to assigning the risk of unanticipated cost increases in the waste program:

- Assign the Risk to Current Ratepayers. Current ratepayers would be forced to bear the risk by paying a fee higher than that calculated to be optimal, thus building into the trust fund assumptions regarding the amount of cost overruns.

- Assign the Risk to Future Ratepayers. Future ratepayers would be forced to bear the risk if an optimal generation fee were calculated using current DOE cost estimates that would have to be adjusted later should these estimates prove wrong.

- <u>Assign the Risk to the Federal Government</u>. The government could bear the risk by promising to meet any costs above those anticipated at the beginning of the program or some other announced level.

- <u>Assign the Risk to Private Investors</u>. A federal corporation could be chartered and licensed by the Nuclear Regulatory Commission to construct and operate the waste disposal repositories. In return for its profit, it would assume responsibility for any cost overruns or other unanticipated financial difficulties with the program.

<u>Assign Risk to Current Ratepayers</u>. Current ratepayers would absorb the risk by paying an initially higher fee. Two arguments can be made for setting the initial fee at a level higher than that warranted by the best current cost estimates. The first is that experience has shown such early estimates to be understated consistently. Hence, a higher initial fee would simply ratify that experience. Second, it can be argued that present electricity users have created the demand for nuclear power plants and have borne the other financial risks of nuclear power. These current electricity users, therefore, should also bear the financial risks of disposing of its wastes.

Three objections may be made to these arguments. First, it is not possible to know how high to raise the fee above current estimates; and indeed, current cost estimates presumably already include substantial margins for error. Second, the existence of a financial cushion might reduce the incentives for efficient program management, thus leading to self-fulfilling cost overruns. Third, future electricity users would also benefit from the same nuclear power plants that serve current users.

<u>Assign Risk to Future Ratepayers</u>. Future users of nuclear electricity would bear the risk if the fee were set at the current optimal level and adjusted upward as events develop. This has the advantage of making the best use of currently available information. But all the surprises would probably raise costs and result in future electricity consumers subsidizing current ones.

<u>Assign Risk to the Government</u>. Although considerations of efficiency and equity suggest that the radioactive waste disposal program should be entirely self-financing, rationales do exist for the federal government to assume the risk that program costs could escalate dramatically. For example, the government, as manager of the program, should bear some part of the responsibility for cost overruns and for the lack of progress that has characterized past efforts. Alternatively, the government could choose to subsidize nuclear energy by assuming some of the risk of cost overruns.

If the federal government decided to absorb cost increases above some stipulated level, the value of this subsidy could be estimated from the value of the trust fund at the end of the program. In the worst-case assumption of cost overruns of 160 percent, utilities would be guaranteed that the generation fee would not exceed the level premised on DOE base-case costs. The implicit subsidy, therefore, would be the present value of the trust fund deficit at the end of the program--that is, the amount of money that the government would have to put into a bank account now to cover this future deficit. This analysis estimates that under this worst case, the federal subsidy would have a present value between $11.5 billion and $12.6 billion, in fiscal year 1982 dollars. A more moderate assumption would have the government absorb costs above those that would raise the fee above some chosen level, say 1.0 mills per kilowatt hour. Under this case, the present value of the federal subsidy would range between $4.0 billion and $5.9 billion, again in 1982 dollars.

Assign Risk to the Private Sector. An alternative to assigning the cost overrun risk to the federal government would be to assign it to the private sector. The Nuclear Regulatory Commission could license a federally chartered corporation, which would exercise a monopoly franchise for waste disposal services, and set rates in the same fashion that the optimal fees are calculated in this report. In effect, the corporation would become a "waste disposal public utility." This approach might minimize real costs through more effective management, and would require the firm's stockholders and management to absorb the risk of cost overruns.

Such a corporation, however, would raise several difficulties. It might be difficult to find private firms interested in providing this service. Licensing requirements might be extraordinarily rigorous, and the liabilities incurred in the event of a major accident might be uninsurable. There is also the possibility that such a firm would fail. If it did, the federal government could end up assuming the responsibilities it had attempted to delegate to the private sector in the first place. And if the government assumed program management, it would either have to raise fees to cover costs or subsidize the program in order to honor the corporation's long-term contracts with utilities.

If neither of these two options--to assign risk to the government or to the private sector--was selected, the issue of risk would devolve on guessing how extensive cost overruns would be over the life of the program, and, in turn, whether to preempt their effects on the trust fund by charging a higher fee than warranted by the DOE base-case cost estimates. In essence, this would be a choice between assigning the risk to current or future ratepayers. Assigning the risk incorrectly could result in intergenerational subsidies in the order of $1.1 billion to $7.3 billion (in fiscal year 1982

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dollars), certainly a significant amount, but less than the level of comparable intergenerational transfers associated with other government programs (notably Social Security).

The foregoing analysis implies that special attention must be given to the engineering cost estimates of the program. Misestimating the project costs could lead to significant redistributions of income between current and future electricity ratepayers. While this analysis has not reviewed those cost estimates, the history of comparable first-time engineering projects of this scale suggests that the danger of significant cost escalation cannot be discounted.

CONCLUDING REMARKS

It is clear that an economically efficient, fair, and effective program for radioactive waste disposal would closely match the users of nuclear-generated electricity with the cost of the program. This analysis suggests that the fees covering these costs are not great--less than 1.5 mills per kilowatt hour, even with large cost overruns. By contrast, the average charge for residential customers of electricity in calendar year 1980 was about 54 mills per kilowatt hour. Regulations, such as the new source performance standards of the 1977 Clean Air Act Amendments raised electricity costs in calendar year 1980 by over 2.3 mills per kilowatt hour on a nationwide basis. In some areas of the country, compliance with the current new source performance standards would raise generating costs as much as 10 mills per kilowatt hour. Radioactive waste disposal fees are likely to be small by contrast.

This has two implications. First, it suggests that waste disposal fees are not likely to be decisive in the economics of nuclear power. Second, it suggests that financing may be a relatively minor issue among the many that surround radioactive waste disposal. Delays in establishing a beneficiary-financed program, however, would lead to the accumulation of spent fuel whose disposal has not been paid for. To the extent this occurs, it would exacerbate concerns with intergenerational fairness.

CHAPTER I. INTRODUCTION

The federal government is responsible for the ultimate disposal of radioactive waste, which is a by-product of nuclear-generated electricity and nuclear weapons production. Since the beginning of the commercial reactor program, nuclear electric utilities have been accumulating spent fuel which is stored in on-site interim facilities. (Military nuclear waste is treated separately.)

Many of these nuclear-powered utilities are now running out of interim storage space--as many as 29 in this decade--and those that do may be forced to shut down or ship the waste to other locations. Obviously, there is a growing need for a federal program to provide final disposal repositories. In response to this need, the Department of Energy (DOE) has proposed a program to construct two geological repositories for long-term waste burial.

The custodianship and disposal of radioactive waste, with its half-life of 10,000 years or more, reflects many concerns, chief among them human health, environmental protection, land use policy, energy policy, state versus federal authority, and the proliferation of capabilities to acquire nuclear weapons. This paper examines the problem from a different perspective: how the nation should pay for the interim storage and ultimate disposal of radioactive waste. Its underlying premise is that economic efficiency, fairness, and, indeed, the capabilities of the radioactive waste program itself will be improved to the extent that the final beneficiaries of the program--the consumers of nuclear-generated electricity--pay its costs, rather than the taxpayers at large. Specifically, this paper addresses the financing requirements of the waste disposal program proposed by DOE to construct two final repositories, scheduled to open in 1994 and 1999, at an estimated cost of $14.8 billion (in 1982 dollars).[1]

A BRIEF PRIMER ON RADIOACTIVE WASTE

Radioactive wastes are of primary concern because of their potential danger to human health and the environment. These wastes contain atoms

1. The DOE schedule has changed since this analysis was begun. The current schedule calls for opening the first two repositories in 1997 and 2002. This change does not affect the conclusions of this paper, however.

whose nuclei decay, emitting energized subatomic particles and electromagnetic radiation. When this radiation interacts with human tissue, or for that matter with any biological material, many molecules are damaged by the breaking of chemical bonds and by ionization, which produces yet further chemical change, producing cancer, genetic mutation, or death. High-level radioactive wastes can be divided into "fission products" and "actinides." For periods up to several hundred years, the dominant risk is from fission products--atoms of medium atomic weight formed by the fissioning of uranium and plutonium. These are principally strontium-90 and cesium-137, although numerous others are present. After roughly 700 years, fission products decay to less than one ten-millionth of their original activity and cease to be of practical concern.

Beyond several hundred years, the dominant source of radioactive hazard is the actinides: heavy atoms of actinium, thorium, uranium, plutonium, and the other "manmade" elements with atomic weights greater than uranium. These are quite toxic and decay relatively slowly, reaching the hazard level of the original uranium ore from which they were derived in about 10,000 years. Thus, the actinides require sequestering from the biological environment for times best measured in geological, rather than historical, terms.

Radioactive wastes are primarily the by-product of commercial nuclear power and nuclear defense activities. Small amounts are also generated through medical applications and other activities that use radioisotopes, but these wastes are relatively small in quantity and low in radioactivity. Hence, the issue is dominated by nuclear fuel and nuclear defense activities. While radioactive wastes are encountered at most stages of the nuclear fuel cycle, those of greatest potential concern are found in spent fuel. The spent fuel from military reactors is chemically reprocessed and the resulting waste stored in retrievable solid or liquid form at three federal installations: the Idaho National Engineering Laboratory near Idaho Falls, Idaho; the Savannah River Plant near Aiken, South Carolina; and the Hanford Reservation near Richland, Washington. Under current plans, these wastes would be immobilized in a solid material before disposal in stable geological formations.

The spent nuclear fuel from commercial reactors is stored temporarily at the reactor sites themselves.[2] These waste materials remain encapsuled

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2. Small amounts of reprocessed commercial waste remain at the site of a closed reprocessing plant at West Valley, New York. In addition, small amounts of commercial spent fuel are stored at West Valley and at another nonoperating reprocessing facility at Morris, Illinois.

in the original fuel assemblies, arrays of zircaloy-clad uranium fuel rods roughly 4 meters long and weighing from 150 to 650 kilograms, depending upon the reactor type. About 25 metric tons are discharged annually from each power reactor.

Once the spent fuel has been withdrawn from the reactor core and cooled in a storage pool on the reactor site, several options are available for its intermediate handling. First, the fuel could simply be stored on-site until a final repository becomes available. But the pools in which many reactors store used fuel are likely to be filled long before a repository could be ready to receive the spent fuel. This concern has motivated a search for other intermediate options: more compact storage of the spent fuel at the reactor site, or shipment to other commercial nuclear plants with more storage capacity or to a special storage site away from the reactor (commonly termed "away-from-reactor" facility, or AFR). Alternatively, the spent nuclear fuel could be "reprocessed"--dissolved in an acid bath, with the remaining uranium and plutonium fuels recycled for further use, and the radioactive wastes separated for final disposal. Although this method is sanctioned by the Reagan Administration, reprocessing is unlikely to become economic in the near future. Furthermore, it raises serious questions of safeguarding the plutonium from diversion to nuclear explosives.[3] Finally, a Monitored Retrievable Storage (MRS) facility has been proposed. The MRS would provide longer-term storage than the AFR, but not permanent disposal. It would preserve the spent fuel until such time as the cost of uranium ore made reprocessing economically attractive. After reprocessing, the wastes would be shipped to a repository for final disposal.

Numerous alternatives have been proposed for the ultimate disposal of nuclear waste--either as spent fuel or as a reprocessed solid. The most developed of these is interment in geological formations of great stability. Salt, basalt, and tuff are now under investigation. Under DOE plans, a repository would be in operation in the United States by 1994 (or 1997 as revised).

FINANCING RADIOACTIVE WASTE DISPOSAL: PRINCIPLES AND PRACTICE

The interim storage and eventual disposal of defense nuclear wastes is paid for by the taxpayers; this is appropriate since the public at large

3. The Carter Administration banned reprocessing as part of its nonproliferation policy.

benefits from defense with nuclear weapons. Although many debate the appropriateness of funding these defense programs through the Department of Energy rather than the Department of Defense, the choice of federal entity does not affect the principle that the government should pay. As long as defense programs pay their full share of any disposal facilities used in common with commercial waste, this principle would not be violated. This full share would include common as well as facility-specific costs. Therefore, this paper deals with financing the disposal of commercial waste from nuclear power plants, for which a method to charge users has not been determined.

For commercial radioactive waste, considerations of economic efficiency, fairness, and effective program management all suggest that the users of nuclear electricity should pay for the services that they receive from the government. These fees could be placed in a special trust fund established to pay for the two permanent waste repositories, as discussed in Chapter III. With regard to economic efficiency, internalizing the cost of waste disposal into the price of electricity would help assure that the economically correct amount of electricity is used and that the correct mix of generating stations are built. As to fairness, the principle that the recipient of a service should bear the cost of providing it (in the absence of an intended subsidy) is well-established. With regard to program effectiveness, charging for waste disposal services might lead utilities and their customers to assume an interest in the efficient management of the program. Perhaps more important, it also might provide a more stable source of funding than is possible under current budgetary constraints.

But the difficult issues in financing radioactive waste disposal do not derive from the abstract merits of user charges. Rather they arise from the way the user charge system would be implemented. If the world were a more certain place, implementation would be straightforward. The tasks of the disposal program and its attendant costs could be specified with precision and assigned to the users of nuclear electricity in direct proportion to the benefits they receive. But the world is not a certain place, and the history of the radioactive waste program suggests that the cost uncertainty normally associated with large and untried technological ventures is compounded by difficult social and political questions. The key financial issue stems from this uncertainty--how shall the risk that actual custodianship and disposal costs might exceed planned costs be borne?

THE STRUCTURE OF THE PAPER

This paper deals with the financial risks associated with the disposal of radioactive waste from commercial power plants. Chapter II describes the